PATENT APPLICATION

TITLE

HUMANIZED ANTIBODIES AGAINST LEUKOCYTE ADHESION MOLECULE VLA-4

Inventors: MARY M. BENDIG, a citizen of USA, residing at 53 Solent Road, West Hampstead, London, NW6 1TX, United Kingdom;

OLIVIER J. LÉGER, a citizen of France, residing at 24 Moxon Street Barnet EN5 5TS, Hertfordshire, United Kingdom;

JOSÉ SALDANHA, a citizen of UK, residing at 22A Lincoln Way, Enfield, Middlesex, EN1 1TE, United Kingdom; and

S. TARRAN JONES, a citizen of UK, residing at 10 The Close, Radlett, Hertfordshire WD7 8HA, United Kingdom.

Assignee: ATHENA NEUROSCIENCES, INC.

Status: Small Entity

TOWNSEND and TOWNSEND KHOURIE and CREW
Steuart Street Tower, 20th Floor
One Market Plaza
San Francisco, California 94105
(415) 543-9600

Example 8: Blocking Properties of Mu 21.6 Antibody

Mu 21.6 was compared with another antibody against α_4 integrin called L25. L25 is commercially available from Becton Dickinson, and has been reported in the literature to be a good
5   inhibitor of $\alpha_4\beta_1$ integrin adhesive function. As shown in Figure 13 (Panel A), both Mu 21.6 and L25 completely inhibited $\alpha_4\beta_1$ integrin-dependent adhesion of human monocytic cells to purified VCAM-1 in the absence of Mn^{+2}. However, in the presence of Mn^{+2} (1 mM) (one of several activators of $\alpha_4\beta_1$
10   integrin) L25 was no longer an effective inhibitor. Similar results were observed when $\alpha_4\beta_1$ integrin was activated by other stimuli. The capacity to block activated $\alpha4\beta1$ integrin is likely to be of value in treating inflammatory diseases such as multiple sclerosis.
15   As a further comparison between mu 21.6 and L25, the capacity of antibody to inhibit human T cell adhesion to increasing amounts of VCAM-1 was determined. In this experiment, increasing amounts of VCAM-1 were coated onto plastic wells of a 96 well assay plate, and the ability of the
20   human T cell line, Jurkat (which expresses high levels of $\alpha_4\beta_1$ integrin), to bind to the coated wells was measured. Values on the Y-axis represent the percentage of Jurkat cells originally added to each well that remained bound after washing the well four times (Figure 13 (Panel B)). This experiment demonstrates
25   that L25 is a good inhibitor of cell adhesion when low levels of VCAM-1 are encountered, but becomes completely ineffective at higher levels of VCAM-1. Mu 21.6, on the other hand, inhibits cell adhesion completely, regardless of the amount of VCAM-1 present. The capacity to block at high concentrations
30   of VCAM-1 is desirable for therapeutic applications because of upregulation of VCAM-1 at sites of inflammation.

Example 9: Efficacy of Humanized 21.6 Antibody in An Animal Model

35   This example establishes the efficacy of humanized 21.6 antibody in prophylactic and therapeutic treatment of EAE in an animal model simulating multiple sclerosis in humans.

(a) Methods
(1) Induction of EAE

The brain and spinal cord were removed from each of five guinea pigs euthanized by CO_2 narcosis. The tissue was kept in PBS on wet ice until it was weighed and homogenized at a concentration of 1 gram of tissue per ml PBS. The tissue was completely homogenized using an electric hand-held homogenizer and subsequently mixed with an equal volume of Freund's complete adjuvant (FCA). FCA was made by adding 100 mg of *mycobacterium tuberculosis* H37 RA (DIFCO, 3114-33-8) to 10 ml of Freund's incomplete adjuvant (Sigma, F-5506). The mixture was emulsified into the consistency of mayonnaise by passing the solution between two syringes connected by a two way stopcock. Each guinea pig was immunized with 600 μl emulsion divided between three sites of administration.

(2) Scoring animals for disease symptoms

The disease symptoms were assessed by prompting each animal to walk and assigning the animal a score by the following commonly accepted criteria:

0	No disease
1	Hind limb weakness
2	Complete hind limb paralysis
3	Complete hind limb and some forelimb paralysis
4	Moribund or dead

(3) Serum and tissue collection

Samples were collected by cardiac puncture from methoxyflurane-anesthetized guinea pigs. About 300-400 μl of blood were collected and placed in microtainer serum separator and allowed to clot for between 20-30 min at room temperature. The tube was then spun for 5 min at room temperature. The serum was drawn off into Eppendorf tubes and stored at -20°C for subsequent analysis of antibody titers by fluorescence activated cell sorting (FACS).

For hematological analysis, blood was collected into ethylenediaminetetraacetic acid-coated microtainer tubes. A 100 μl aliquot was aspirated into an acridine-coated hematocrit tube. The tube was capped and the blood was mixed with acridine orange by gently inverting the tube 15 times. A float

was put into the hematocrit tube and the sample was centrifuged for 5 minutes. The hematocrit tube was placed into a precalibrated Idexx QBC Vet Autoreader designed for quantitative buffey coat analysis. Values were read under the horse calibration system and adjusted to guinea pig equivalents using a predetermined conversion factor.

At the end of the experiment, the guinea pigs were killed by CO_2 narcosis and the brains and spinal cords removed. Half of the brain and spinal cord from every guinea pig was snap frozen in 2-methyl butane on dry ice (-20 to -40°C). This tissue was cut and immunostained with a pan macrophage marker (Serotec MCA-518) and a T-lymphocyte marker (Serotec MCA-751) using the avidin-biotin linking peroxidase assay (Vector Laboratories, Inc., Burlingame, CA) and diaminobenzidine as a chromagen. The tissue was scored for cellular infiltration according to the following scoring system:

0	No infiltrating cells.
0.5	Very little staining; may be artifactual; usually associated with vessels.
1	Staining of a few cells (less than 15) usually near a vessel.
2	Staining of many cells (20-50), usually radiating out from a vessel.
3	Staining of many cells (> 50) scattered throughout the tissue; many cuffed vessels.

(b) Prophylactic Treatment

This experiment was designed to evaluate the efficacy of humanized 21.6 antibody in delaying the onset of clinical symptoms. Previous data have demonstrated that leukocyte influx into the brain and spinal cord of EAE guinea pigs typically starts between day 7 and day 8. Therefore, antibodies were administered on day 7 and on day 10 post-immunization. To compare mouse and humanized 21.6 antibody, equivalent doses of each of the antibodies (3.0, 0.30 and 0.03 mg/kg) were administered. Preliminary pharmacokinetic studies revealed that saturating blood levels of mouse 21.6

antibody were attained within 24 hours after subcutaneous administration, and remained elevated up to 48 hours.

On day 11, 24 hours after the second dose of antibody, blood samples were drawn from three randomly selected animals
5 in each group. For each treatment group a mean for the number of days for each guinea pig to reach a clinical score of 1 was calculated (Table 7). The mean value for the PBS-treated group in this experiment was 11 days post-immunization (which is typical of previous results). Treatment with the highest dose
10 of humanized and mouse antibody resulted in a significant delay of disease by 4.6 (p=0.000) and 3 (p=0.007) days, respectively. The lower doses of antibody had no effect on the course of disease.

15

Table 7

Effect of mouse or humanized 21.6 antibody on
time post immunization to reach a clinical score of 1.

GROUP	1	2	3	4	5	6	7
mg/kg	0.03 M[#]	3.0 H[@]	3.0 H	3.0 M	0.03 H	PBS	0.3 M
	8	9	13	10	8	9	9
	9	10	15	12	10	9	9
	9	10	15	14	10	11	11
	9	11	16	14	11	11	12
	11	11	16	14	12	11	12
	12	11	16	15	12	12	13
	12	12	17	15	12	12	13
		13	17	18	12	13	
Mean ± SD	10.0 ± 1.6	10.9 ± 1.2	**15.6 ± 1.3	*14.0 ± 2.3	10.9 ± 1.5	11.0 ± 1.4	11.6 ± 1.4

[@] H denotes humanized antibody; [#] M denotes mouse.
**p=0.000 and *p=0.007, as compared to PBS.

30

Daily body weights of the guinea pig reflected a similar effect of the high doses of humanized and mouse antibody. (Figure 14). Animals in these treatment groups steadily gained weight. Guinea pigs in all other treatment groups lost
35 weight starting from just before the day of onset of disease.

Serum titers of antibody were measured in three randomly selected animals from each group by cardiac puncture on day 11, roughly 24 hr after the second treatment. Efficacy of the antibodies to delay disease correlated tightly with serum
5 levels. About 20 μg/ml serum antibody was present in the circulation of all animals injected with the highest dose of both humanized and mouse antibodies. This concentration is of the same order of magnitude as the concentration of 21.6 antibody required to saturate VLA-4 sites *in vitro*. In
10 contrast, animals from all other groups had little to no detectable serum antibody.

(c) Reversal of On-going Disease

About 60 guinea pigs were immunized and allowed to
15 develop clinical symptoms of EAE. On day 13, all guinea pigs that attained a clinical score of 1 were randomly assigned to a treatment group. Figure 15 shows that animals treated with 3 mg/kg humanized antibody began to recover hind limb function within 48 hr of treatment. On Days 17 and 18, one and two
20 days after the second dose, all eight animals were disease free. ANOVA of the area under the curve values for each treatment group revealed that only the 3 mg/kg humanized antibody treated group value was statistically lower than the PBS control group (p=0.042). These animals progressively
25 gained weight within 24 hrs after the first administration until the experiment was terminated on Day 19 (Figure 16).

Antibody serum titers were measured by FACS analysis on samples taken 24 hrs after the first injection (Day 14) and at sacrifice (Day 19). Treatment with mouse 21.6 antibody
30 resulted in slightly lower serum antibody titers than treatment with humanized 21.6 antibody (9.1 vs. 12.6 μg/ml). This difference became more profound on Day 19, three days after the second administration, when there was very little detectable serum mouse antibody, while the levels of humanized
35 antibody on Day 19 had dropped below saturating but were still measurable (6.1 μg/ml). These data demonstrate a correlation between plasma levels of antibody and physiologic efficacy and

suggest that the effective circulating antibody level is in the range of 10-20 µg/ml in the guinea pig.

Leukocyte infiltration onto brain and spinal cord was evaluated in tissue from animals killed on Day 19. Table 8
5 shows significant differences in the degree of infiltration as a function of antibody treatment. The reduction in T cell infiltration into brain and spinal cord and macrophage infiltration into spinal cord was significant after treatment with 3 mg/kg. Lower doses tended to reduce infiltration, but
10 did not reach significance. There was no significant difference in cellular infiltrate of macrophages into the spinal cord at any dose. Since the immunohistochemical technique used to evaluate macrophages does not distinguish resident from invading cells, the lack of effect on
15 macrophages likely represents the sustained presence of resident macrophages and microglia.

The reduction in T-cells and monocytes in brain tissue by administration of the antibody after establishment of the disease suggests that cell trafficking is not a cumulative
20 process, but a dynamic movement of cells into and out of CNS tissue. Importantly, the data suggest that interruption of the entry of leukocytes into parenchymal tissue allows the CNS to rid itself of the invading pathological element.

25   **Table 8**

Significant differences in T-cell and macrophage
infiltration into brain and spinal cord on Day 129.

30   BRAIN   SPINAL CORD

GROUP PBS	T-CELLS	MACROPHAGES	T-CELLS	MACROPHAGES
3 mg/kg @ H	p=0.001	p=0.005	p=0.007	NS
3 mg/kg # M	p=0.001	p=0.005	p=0.008	NS
1mg/kg H	NS	NS	NS	NS
0.3 mg/kg H	NS	NS	NS	NS

NS = not significant.
40

Hematology data revealed that treatment with mouse or humanized 21.6 antibody caused no difference in whole white blood cell counts, mononuclear and granulocyte number or in red blood cell count. The high dose of mouse or humanized

5 antibody resulted in a significant increase in platelet counts as compared to PBS treated animals (Table 9). In normal guinea pig platelet counts are 755 ± 103 cells/ml, about double that of PBS–treated EAE animals. Thus, treatment with doses of mouse and humanized antibody that effectively

10 reversed disease, also restored platelet count to normal.

Table 9

Effect of antibody treatment on platelet count in EAE animals.
15

TREATMENT	PLATELETS X 10^{-6} CELLS/ML
++Non EAE guinea pigs	755 ± 103 (9)
PBS	373.7 ± 167.5 (7)
3 mg/kg @ H	622.2 ± 97.0 (6) **
3 mg/kg # M	587.5 ± 57.8 (6)
1 mg/kg H	578.3 ± 123.2 (6)
0.3 mg/kg H	492.5 ± 168.6 (6)

++ Platelet counts in non–EAE guinea pigs were determined in a
25 separate experiment.

*p=0.05 vs PBS.

30   In conclusion, both humanized and mouse 21.6 antibodies are effective in delaying and reversing clinical symptoms in an animal model simulating multiple sclerosis in humans. The humanized antibody is more effective than the same dosage of mouse antibody in reversing symptoms.

35   Although the foregoing invention has been described in detail for purposes of clarity of understanding, it will be obvious that certain modifications may be practiced within the scope of the appended claims. All publications and patent documents cited above are hereby incorporated by reference in